A STUDY OF THE STABILITY OF THE TOP CHORDS OF PONY TRUSSES

BY

PING CHUN WANG

B.S., National Central University, China, 1943
M.S., University of Illinois, 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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Introduction

On surveying past practice in bridge design and construction one gets the impression that the use of pony trusses (half-through trusses) has been limited for the most part to lightly loaded (highways) short span gridges in which the question of lateral stability of the top chords, due to absence of the top laterals, has not been very important. In recent years the more frequent use of pony trusses for moderately long spans and even for short continuous spans, has made the question of the stability of the top chords a problem of increasing importance. The 1949 edition of the specifications for the design of highway bridges published by the American Association of State Highway Officials requires that the top chord be considered as a column with elastic lateral supports.

The purpose of this thesis is to make a study of the existing literature and develop a workable method — a method which can be used by the average engineer who knows the fundamental principles — of investigating the stability of the top chord of pony trusses.

Resistance Of The Web Members To Lateral Buckling Of The Top Chords Of Pony Trusses

As the top chord of a pony truss tends to buckle laterally, each panel point has the possibility of three types of movement: a rotation in the horizontal plane, a rotation in the transverse vertical plane, and a lateral translation. Opposing the tendency to these three types of movement, the web members meeting at that panel point offer three types of resistance: a moment in the horizontal plane, a moment in the transverse vertical plane and a force in the lateral direction. If the connections between the web members and the chord are assumed as hinged, i.e. if it is assumed that the chord can

rotate freely with respect to the web members both in the horizontal plane and in the transverse vertical plane, these three types of resistance reduce to only one, the resisting force in the lateral direction.

Two typical combinations of web members are considered: a single vertical and a vertical combined with two diagonals. The resistance of a single vertical can be computed from its flexural, shearing and torsional stiffnesses, and the resistance of the combination of a vertical and two diagonals can be obtained by combining the stiffnesses of the individual members.

Historical Review

Four existing methods of investigating the stability of the top chords of pony trusses are reviewed: (i) Engesser's, (ii) Bleich's, (iii) Mueller-Breslau's and (iv) Timoshenko's.

In the methods suggested by Engesser, Bleich and Timoshenko, it is assnmed that: (a) the top chord of a pony truss is of uniform cross section; (b) the ends are hinged; (c) the verticals alone are effective in resisting lateral buckling of the chord; and (d) the verticals are of equal rigidity. The resistance of the verticals is assumed as uniformly distributed along the chord by Engesser and Timoshenko. Engesser and Bleich further assume that the compressive forces tending to cause buckling of the chord are constant, while Timoshenko assumes a parabolic variation for the compressive forces in the chord.

The most exact of the four methods is that of Mueller-Breslau. His method is applicable to trusses with non-prismatic top chords, with verticals of different rigidities and with different compressive forces in the various segments of the chord. However, the solution of the simultaneous homogeneous equations, resulting from his analysis, is a rather formidable task.

Based on the method discussed above, two curves for preliminary investigation of the stability of the top chords of

pony trusses are given: one for parallel chord trusses and the other for segmental chord trusses.

Investigation Of The Stability Of The Top Chords Of Pony Trusses By The Method Of Rotation And Translation

The method of rotation and translation, devised by the writer, uses as its basic tools the beam constants for axially stressed members. It introduces a systematic procedure for finding the moment (or force) required to rotate (or translate) any panel point through a unit angle (or distance) including the effect of the elastic restraints of the panel points, and establishes a criterion for stability based on these quantities. It is shown that if the moment in the horizontal plane and the moment in the transverse vertical plane required to produce a positive unit rotation in those planes, and the force in the lateral direction required to produce a positive unit lateral translation are positive simultaneously, the chord is in a stable condition.

In applying the method, all panel points of the chord are first considered to be fixed against all types of movement (rotation in the horizontal plane, rotation in the transverse vertical plane and lateral translation). Then starting from each end of the truss, each panel point of the top chord is treated in two steps as typified for an interior panel point in the following paragraphs:

(i) The panel point under consideration is released from one type of fixity and allowed to undergo a unit movement pertinent to that type of fixity. All the remaining types of fixities at that panel point and all types of fixities at its adjacent panel points are maintained. The end moments and shears thus introduced are simply the beam constants (of the segments of the chord involved) pertinent to the type of fixity which is released.

(ii) All types of fixities at the adjacent panel point - the panel point which has been treated prior to the panel point

under consideration - and all the remaining types of fixities at the panel point considered are then released, while the unit movement produced in step (i) is maintained. The correcting end moments and shears thus introduced are added to the beam constants resulting from the application of step (i).

The end moments and shears resulting from the application of steps (i) and (ii) are those which will occur if the panel point under consideration undergoes a unit movement of a certain type, while that panel point and the panel point previously considered are under actual elastic restraints.

The same procedure is repeated for the remaining types of movement of the same panel point and all types of movement of the following panel points until the designated panel point is reached.

Two examples are presented to illustrate the method: one for a parallel chord truss and the other for a segmental chord truss.

The method of rotation and translation is believed to be applicable to all kinds of trusses. The method makes it possible to take account of variable cross sections in the chords, different rigidities in the web members, variations in the compressive force in the chords and also the torsional resistance of the members.

Design Procedure And Example

After a pony truss has been designed using the ordinary methods of computing stresses and selecting sections, a preliminary investigation of the stability of the top chord can be made by using preliminary design curves. If necessary, a final check may be made by the method of rotation and translation.

A highway bridge truss with a span of 160 feet and a roadway 26 feet in width is used as an example to illustrate the recommended procedure.

VITA

Ping-chun Wang was born in Kiangsu, China, on March 10, 1920. He graduated from National Central University, Chung-king, China, with the degree of Bachelor of Science in Civil Engineering in July, 1943.

During the period from September 1943 to September 1947, he was associated with the China Bridge Company. His practical experience consists of design and erection of a 100 feet span highway pony truss, preliminary survey and design of a 1500 feet span suspension bridge over the same river at Hankow, China.

He worked during the summer of 1949 at the Bethlehem Steel Company where he obtained valuable material concerning the problem of the elastic stability of pony trusses.

He was elected an associate member of Sigma Xi in August 1948 and a Junior member of the American Society of Civil Engineers in March 1950.

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